You have downloaded a document from
RE-BUŚ
repository of the University of Silesia in Katowice

Title: The Changes of P-Wave Velocity of Rock Samples Over Time

Author: Iwona Stan-Kłeczek, Adam F. Idziak

Citation style: Stan-Kłeczek Iwona, Idziak Adam F. (2001). The Changes of P-Wave Velocity of Rock Samples Over Time. “Procedia Engineering” (Vol. 191 (2017), s. 483-487), doi 10.1016/j.proeng.2017.05.207

Uznanie autorstwa - Użycie niekomercyjne - Bez utworów zależnych Polska - Licencja ta zezwala na rozpowszechnianie, przedstawianie i wykonywanie utworu jedynie w celach niekomercyjnych oraz pod warunkiem zachowania go w oryginalnej postaci (nie tworzenia utworów zależnych).

UNIWERSYTET ŚLĄSKI W KATOWICACH
Biblioteka Uniwersytetu Śląskiego
Ministerstwo Nauki i Szkolnictwa Wyższego

Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 191 (2017) 483 – 487

Procedia Engineering

www.elsevier.com/locate/procedia

Symposium of the International Society for Rock Mechanics

The Changes of P-Wave Velocity of Rock Samples Over Time

Iwona Stan-Kłeczek*, Adam F. Idziak

The University of Silesia, Faculty of Earth Sciences, Będzińska 60, 41-200 Sosnowiec, Poland

Abstract

The main aim of this study was to determine the variation of the P- wave velocity of carbonate rocks over time. Samples of carbonate rocks like dolomite and limestone were carried out from three quarries. The study was done in May and November 2015. To test equipment Pundit Lab+ was used, which measure the transmission time of ultrasonic wave. On the base on the transmission time P- wave seismic velocities were calculated. It allows to compare the results obtained for one time interval and to calculate, using the Student's t test, if differences of P- wave seismic velocity values are significant.
© 2017 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of the organizing committee of EUROCK 2017

Keywords: ultrasonic measurement; P- wave velocity; carbonate rocks

1. Introduction

Determination of the physical and mechanical properties of rocks is the most interesting problem which is still not definitely solved despite of a lot of scientists who try to do it. It seems to be very important to make an assessment of the elastic properties of rocks which can be studied in laboratory using cylinder samples [3–5, 7–9, 13] and also directly in quarries using geophysical methods [10, 14]. The rock under the influence of external forces undergoes compression and decompression. The deformation of the body is the result of moves of its particles relative to each other. Rocks within the rock mass there are under the pressure of the surrounding rocks. Depending on the pressure size, rocks there are in a specified state of compression and a specified state of deformation [1, 2, 6]. At the moment of output from the deposit and remove the existing pressure, annealing process begins and elastic strain decays. The decompression of rock causes the change of properties such as hardness, grindability, porosity and strength. In addition to decompression phenomena, another process takes place like moisture loss.

* Corresponding author. Tel.: +48-32-368-9511.
E-mail address: iwona.stan-kleczek@us.edu.pl

1877-7058 © 2017 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of the organizing committee of EUROCK 2017
doi:10.1016/j.proeng.2017.05.207

In the process of deposit documentation the tests are done immediately after extraction of the rock from the rock mass but in many cases, these tests are carried out after a certain time when the analysed samples were stored by some time under certain conditions.

The study of the P- wave seismic velocity shows the importance of the time factor to determination of the physical parameters of a sample.

The measurements of the seismic wave velocity were performed in three Triassic carbonate quarries: one limestone deposit (deposit 1) and two dolomite deposits (deposit 2 and deposit 3). From each quarry blocks of rocks were collected to laboratory measurements.

2. Laboratory measurements

From blocks of rocks were cut cuboids with a length of 0.1 m and section 0.05 m x 0.05 m. The Ultrasonic Instrument Pundit Lab+ Swiss company Proceq was applied. The ultrasonic impulses are repeatedly transmitted to the sample and then recorded as the time (t) of the ultrasonic wave passing through the sample. The rock specimens were mounted between the transmitter and receiver transducer holders. The length of sample is a way (s). It is possible to calculate the velocity (v) using the formula v = s / t. In order to ensure close contact between the surface of sample and transducers it was used special paste. The frequency of elastic signals used for transmission measurement is 250 kHz. The pulse length is 2μs. The accuracy of time of arrival of P- wave is 1 μs. The research included approximately 3000 measurements in May [11] and approximately 2500 in November. The samples were stored in room temperature. The study was performed using three samples from each quarry. The anisotropy coefficient k was calculated for each sample from equation:

$$k = \frac{v_{p\max} - v_{p\min}}{v_{p\,mean}} \cdot 100\% \tag{1}$$

average of the velocities corresponding to all measured directions. The values of the maximum and minimum velocities and coefficients of anisotropy are summarised in Table 1.

3. Result and discussion

The obtain P- wave velocity values, measured at an interval of half a year, have not shown significant differences (Table 1, Fig. 1). In the case of deposit 1 the seismic wave velocity value was higher in May than in November. In the case of deposits 2 and 3, the situation is reversed, the seismic wave velocity is higher after six months.

The samples of beige limestone from the deposit 1 characterise by cracks filled with calcite. In the sample 1 cracks are not visible on the surface but there are numerous small cracks in length in the range of from 1–2 mm to 20 mm. The velocity values and anisotropy coefficient k = 11 % indicate on the anisotropy. In the sample 2 it is observed two cracks perpendicular respectively to axis 1 and 2. These cracks cause that velocities in this sample have similar values for all axes and the coefficient k = 3.6 % does not indicate the presence of the anisotropy. In the sample 3 we can also see cracks with a diameter of 2 mm and filled with calcite, air or clay material. Values of the velocity and the coefficient k show a distinct anisotropy. The highest value of velocity 6800 $m \cdot s^{-1}$ occurs in a plane parallel to the cracks.

The grey limestone sample coming from the deposit 2 contains the inclusions of calcite with spherical or hemispherical shape. The packing of inclusions parallel to axis 1 and 3 causes the occurrence of the anisotropy.

Obtained values of velocities for deposit 1 are larger than of the deposit 2 what may be due to the effect of unstressing or the difference between the physical properties of the rocks.

The structure of dolomite samples from the deposit 3 has a more homogeneous character hence the coefficient k has a smaller value. The samples are dark yellow to gray color. In the samples 1, 2 and 3 there are open cracks of 0.1 mm filled with clay material. These cracks are perpendicular to the axis 1.

The samples from the deposit 4 have a light yellow color. In the sample 1 there are not visible cracks which is reflected in the measured values of velocity which have very similar value about 5200 $m \cdot s^{-1}$ and the anisotropy coefficient k is equal 3.5 %. In the sample 2 there is a calcite filled crack with an opening 0.2 mm. This crack is parallel to axis 2 and it is visible in the velocity value equal 5550 $m \cdot s^{-1}$. The anisotropy coefficient is equal 15 %. In the sample 3 the situation is similar and the crack is parallel to axis 1. In this sample there are very small cavities with diameters in the range from 0.8 mm to 6 mm filled with calcite or air.

Table 1. Results from laboratory measurements.

Deposit	Sample	May				November		
		Axis	1	2	3	1	2	3
1	1	v_P [$m \cdot s^{-1}$]	6840	6380	6120	6620	5890	6120
		k [%]	11.0			11.7		
	2	v_P [$m \cdot s^{-1}$]	6060	6280	6280	6030	5890	5960
		k [%]	3.6			2.0		
	3	v_P [$m \cdot s^{-1}$]	6010	6810	6290	5560	6430	5700
		k [%]	12.6			14.7		
2	1	v_P [$m \cdot s^{-1}$]	4370	4740	4780	4690	5160	4860
		k [%]	9.0			10.0		
	2	v_P [$m \cdot s^{-1}$]	4790	4990	4850	4810	4930	5010
		k [%]	4.0			4.0		
	3	v_P [$m \cdot s^{-1}$]	4920	4710	4970	49670	5120	4980
		k [%]	5.5			3.0		
3	1	v_P [$m \cdot s^{-1}$]	5160	5260	5340	5290	5250	5230
		k [%]	3.5			1.0		
	2	v_P [$m \cdot s^{-1}$]	4770	5550	5120	5370	5450	5220
		k [%]	15.0			4.0		
	3	v_P [$m \cdot s^{-1}$]	5400	4930	5480	5350	4990	5490
		k [%]	10.0			9.4		

The Student's t test was used in order to verification of differences between P- wave seismic velocities. This test allows to check the hypothesis whether the average values of P-wave velocity of the two periods are equal [12].

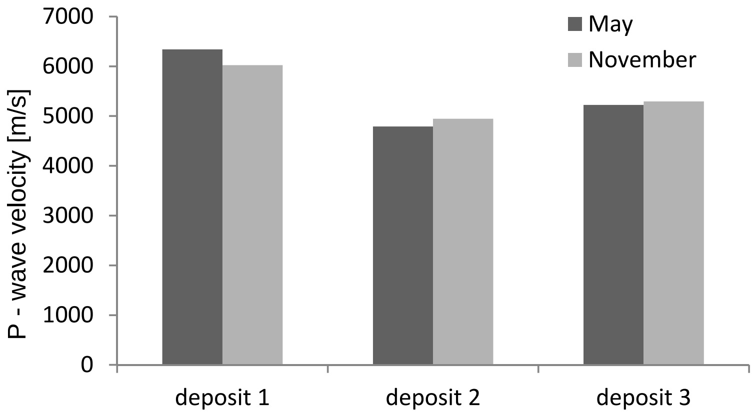

Fig. 1. The average value of P - wave velocity calculated for time interval.

It was assumed that the distribution of the mean value of velocity in both periods is a normal distribution. The test was done for each quarry. On the base of results of two small samples (three specimens) it was verified the null hypothesis that the mean value of P - wave velocities were equal to the alternative hypothesis that they were different. The level of significance was α = 0.5. The results show that there is no evidence to reject the null hypothesis, i.e. the mean values of P-wave velocity obtained for two time intervals are equal and differences in the values of mean velocity they are not statistically significant. The obtained results have not proved the importance of the half year interval and it does not mean that more data could provide the expected difference. For each sample the relative error of P- wave seismic velocity was calculated (Table 2).

Table 2. The relative error of P-wave velocity ΔV/V [%]. M – May, N – November.

Deposit	Sample	1			2			3		
	Axis	1	2	3	1	2	3	1	2	3
1	M	0.68	1.27	1.19	0.62	1.28	1.46	0.32	1.28	0.74
	N	0.65	1.19	0.71	0.80	1.20	0.71	1.73	1.19	1.89
2	M	3.51	2.41	1.36	0.96	1.65	1.74	1.26	4.48	0.60
	N	0.23	0.49	0.64	0.72	0.49	0.49	0.26	5.06	0.60
3	M	1.24	0.62	0.63	28.21	1.52	11.71	1.32	1.52	2.48
	N	2.91	1.01	0.63	0.66	1.63	5.47	0.32	1.13	2.86

The calculated relative error of P - wave seismic velocity is in the range from 0.3 to 3 %. However, there are two results significantly deviating from the rest (11.7 % and 28 %). These values are designated for samples from the deposit 3. The high values are associated with the heterogeneity of the samples.

4. Conclusion

The results indicate that measurements of P- wave velocity made at an interval half a year did not show major differences. On the basis of the obtain P- wave velocity and measured S-wave velocity it will be possible to determine the physical properties of rocks [11]. The obtain results gave no a clear difference. One of the reason could be too short time interval used in the case of carbonate rocks. The second reason is the insufficient number of samples. The Student's t test also confirm presented considerations and not proved the importance of the half year interval.

Acknowledgments

The project has been financed from the funds of the Leading National Research Centre (KNOW) received by the Centre for Polar Studies for the period 2014–2018.

References

[1] N. Barton, Rock quality, seismic velocity, attenuation and anisotropy, Taylor & Francis Group. London, UK, 2007.
[2] S. Crampin, R. McGonigle, D. Bamford, Estimating crack parameters from observations of P-wave velocity anisotropy, Geophysics 45(1980) 345–360.
[3] M. Fener, The effect of rock ample dimension on the P-wave velocity, J Nondestruct Eval 30 (2011) 99–105.
[4] Y. Gueguen, A. Schubnel, Elastic wave velocities and permeability of cracked rocks, Tectonophysics 370 (2003) 163–176.
[5] A.H. Hammam, M. Eliwa, Comparison between results of dynamic & static moduli of soil determined by different methods, HBRC Journal 9 (2013) 144–149.
[6] S. Kozłowski (Ed.), Metodyka badań surowców skalnych, Wydawnictwa Geologiczne, 1979, pp. 356–362 (in Polish).
[7] A. Mockovčiaková, B. Pandula, Study of the relation between the static and dynamic moduli of rocks, METABK 42(1) 37 (2003) 37–39.
[8] A.R. Najibi, G. Mohammad, G.R. Lashkaripour, M.R. Asef, Empirical relations between strength and static and dynamic elastic properties of Asmari and Sarvak limestones, two main oil reservoirs in Iran, Journal of Petroleum Science and Engineering 126 (2015) 78–82.
[9] J. Pinińska, P. Płatek, Badania ultradźwiękowe w ocenie wytrzymałościowej skał, Górnictwo odkrywkowe tom 2-3 (2002) 89–96, (in Polish).
[10] I. Stan-Kłeczek, A.F. Idziak, Anisotropy of elastic properties of rock mass induced by cracks, Acta Geodynamica and Geomaterialia 5, No. 2 (150) (2008) 153–159.
[11] I. Stan-Kłeczek, The study of the elastic properties of carbonate rocks on a base of laboratory and field measurement, Acta Montanistica Slovaca 21 (2016) 76–83.
[12] A. Stanisz, Przystępny kurs statystyki, Tom 1. Statystyki podstawowe. StatSoft, 2006 (in Polish).
[13] F. Tripetta, C. Collettini, P.G. Meredith, S. Vinciguerra, Evolution of the elastic moduli of seismogenic Triassic Evaporites subjected to cyclic stressing, Tectonophysics 592 (2013) 67–79.
[14] J. Vilhelm, V. Rudajev, R. Živor, T. Lokajicek, Z. Pros, Influence of crack distribution of rocks on P- wave velocity anisotropy – A laboratory and fild scale study, Geophysical Prospecting 58 (6) (2010) 1099–1110.